AAV IRAM TRANSMISSION REVIEW

INTERIM REPORT
TFLRF No. 334

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The objective of this program was to provide the United States Marine Corps Logistics Bases, Albany, GA, engineering support services for the AAV IRAM transmission. The TARDEC Fuels and Lubricants Research Facility (TFLRF) at Southwest Research Institute (SwRI), in conjunction with AERA, Inc. was tasked to perform an independent assessment and evaluation of past literature and seal, housing, and fluid problems and other failures modes related to the IRAM transmission.

Visits were made to Logistics Bases, Albany; GA, Barstow, CA; and 29 Palms, CA to discuss problem areas and evaluate an on-going field demonstration. The preferred cast iron seal ring was selected based on the field demonstration. Other problem areas with the IRAM transmission had already been addressed AERA or solutions are currently in progress.

14. SUBJECT TERMS

IRAM transmission, cast iron seal rings, slippers, hydrostatic steering unit (HSU), tube swagging, cracks, power take-off, (PTO), welding, USMC Logistics Bases

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EXECUTIVE SUMMARY

Problem - The AAV is an aging vehicle. Due to additional weight and mission requirements, the vehicle is unable to perform as originally designed. In additional, some components have been changed due to lack of availability, upgrading, and suppliers going out of business. Some components have reduced the mean-time-between failures to an unacceptable level.

Objective - The objective of this program was to provide the United States Marine Corps Logistics Bases, Albany, GA, engineering support services for the AAV IRAM transmission. The TARDEC Fuels and Lubricants Research Facility (TFLRF) at Southwest Research Institute (SwRI), in conjunction with AERA, Inc. was tasked to perform an independent assessment and evaluation of past literature and seal, housing, and fluid problems and other failures modes related to the IRAM transmission.

Importance of Project - Determination of problem areas and providing a solution would increase combat readiness and reduce maintenance costs.

Technical Approach -TFLRF working in conjunction with AERA, Inc. would review past literature, visit logistic bases to interview maintenance personnel, and provide technical assistance at the 29 Palms, CA field demonstration evaluation.

Accomplishments - Review of literature revealed AERA had provided the Marine Corps with sound engineering assistance and realistic recommendations. The field demonstration provided the required data to select a preferred cast iron ring for the housing cover. The OEM cast iron rings appeared to be defective and poor quality.

Military Impact - The engineering and technical support provided by the TFLRF and AERA will increase combat readiness, reduce down time, and reduce maintenance costs.

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FOREWORD/ACKNOWLEDGMENTS

This work was performed by the U.S. Army TARDEC Fuels and Lubricants Research Facility (TFLRF) located at Southwest Research Institute (SwRI), San Antonio, TX, during the period July 1997 to December 1997 under Contract No. DAAK70-92-C-0059. The work was funded by the United States Marine Corps Logistics Bases, Albany, GA. Mr. T. Bagwell (AMSTA-TR-D/210) of TARDEC serving as technical monitor and Mr. L. Villahermosa (AMSTA-TR-D/210) of TARDEC serving as the contracting officer's technical representative.

The authors would like to acknowledge the assistance of Lt. Col. Deanes, Major J.D. Langlinais, USMC Logistics Bases, Albany GA, and Jim Dillion, Barstow, CA, for their assistance with this program. The authors wish to thank Ms. D. L. Wright and Ms. K.M. Kelley for report preparation.

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1.0 OBJECTIVE

The objective of this program was to provide the United States Marine Corps Logistics Bases in Albany, GA engineering support services for the AAV IRAM transmission. Southwest Research Institute (SwRI), in cooperation with AERA, Inc., was tasked to perform an independent assessment and evaluation of the seal, housing, and fluid problems and other failure modes related to the IRAM transmission.

2.0 VALIDATION REPORT

The initial phase of this program was to review the engineering analysis, studies, and other reports provided by AERA, Inc. and other authors.

2.1 IRAM Transmission: Historical Research and Failure Data Analysis; Volumes I, II, and III (1)

The "IRAM Transmission: Historical Research and Failure Data Analysis, Volumes I, II, and III, were reviewed by SwRI personnel. This comprehensive report reviewed the IRAM transmission failures to date. The report was found to be complete, with sound engineering practices, and reasonable suggestions given the available information. The following is a partial list of some of the more relevant tasks AERA, Inc. performed over the past years. Other information is presented in the main report.

2.1.1 Investigation of Hydrostatic Steering Unit (HSU) Problems

Three taskers were initiated to investigate problems with the hydrostatic steering unit (HSU).

The first tasker researched the re-slippering option with non-OEM parts. The report mentions debris in the HSU system and Sunstrand's contention that a separate fluid system is needed for the HSU. HSU failures due to slipper problems or overloading due to the HSU being undersized continue to be an issue.

The second tasker was a discussion of the failure of eight HSU's and the teleconference, which was held on 11 April 1996. The same issues as discussed in the previous task were discussed. There

were slipper dimensional and material composition deviations from the TM, and Sunstrand restated their contention that the fluid was contaminated.

For the third tasker, AERA proposed additional inspection criteria for the slippers due to failures using the Grand Prix Associates (GPA) slippers. The MC3 was forced to reverse engineer these parts when Sunstrand would not provide the part drawings. It was believed that the failures were a result of shortcomings in the reverse engineering process. The problem was eventually eliminated by discontinuing the use of the GPA slippers.

2.1.2 Tasker Evaluation AIN 65-T019, Tube Swaging

AERA reviewed the swaging process of the oil tubes in the transmission cases. This is an important issue representing the second highest cause of transmission failures. With the high probability the oil seal problem has been solved by using the cast iron hook seal ring, tube swaging will become the next major hurdle to overcome. Additional information is available later in this report.

2.1.3 Tasker Evaluation, HSU Resleeving Process

This task was to validate the MCA HSU resleeving process. A 100-hour evaluation of the test piece was conducted. Pre- and post measurements were made and a written rebuild procedure followed. This work was completed and carefully documented. Realizing budgetary constraints may have been involved, SwRI would suggest to gain additional data, a pre- and post test to have been performed on the test stand under simulated steering load to document any change in performance over the 100 hours, in addition to a documented baseline.

2.1.4 AIN 75-T067 AAV Rework/Failure Resolution, January 1996 Conference

This report was a summary of the Failure Resolution Meeting held in January 1996. Issues, which had been discussed in greater detail in other reports, were reported on. Cooperation between the MCs appeared to be good.

2.1.5 Tasker Evaluation AIN 75-T070, Housing Bearing Bore Resleeving

This report evaluates the practice of resleeving the seven main bearing bores. The practice of resleeving has proven successful over the past seven years. A related issue is the practice of maintaining parallelism between the shafts, but allowing the perpendicularity with the transmission case to be compromised. One consequence of this will be the possibility of shafts contacting the oil supply housings. Another consequence may be the reduced life due to angular misalignment.

2.2 Review of Amphibious Vehicle Test Branch (AVTB) Test Reports

2.2.1 IRAM Transmission Evaluations

The Amphibious Vehicle Test Branch (AVTB) at Camp Pendleton, CA was visited to gather information on IRAM and RAM transmission testing. The AVTB appears to have a highly skilled, trained, and motivated staff with good test facilities for conducting the IRAM testing.

The 600-hour IRAM transmission enduro performed by AVTB was done in two parts. The first part consisted of a standard test procedure that evaluated steering, pivot steer, braking, and shift performance. The second part consisted of a repeating 12.5-hour mission profile of 80% land and 20% water operation performed on the Camp Pendleton training range. The IRAM enduro looked at the MTBF of components and did not include instrumentation and data logging of transmission performance.

The six IRAM transmissions evaluated by AVTB included two pre-production units and four early production units. Testing was halted on various transmissions for reasons including the following:

- Seal rings
- Tubes cracking and breaking due to nylon support block mismatch
- Torque converter seal carrier assembled with insufficient side clearance
- HSU failures due to bad slipper shoes resulting in excessive wobble plate wear, piston failures, and snap ring failures
- PTO keyway failure due to loss of pressfit on gear and PTO idler bearing failure
- Clutch drum snap ring falling out of clutch due to improper installation, possibly insufficient snap ring tension and no blocking land.

Assembly errors (2, 3, 5, and 6) discovered during the evaluations have been investigated and resolved. Of the six transmissions evaluated, only one completed the 600-hour endurance test. However, the transmission that did complete the evaluation had several stoppages of testing due to component malfunctions. Some of the stoppages were due to IRAM issues that since have been addressed and resolved, such as the seal rings and tube swaging.

The AVTB testing revealed non-IRAM transmission components that may be reaching the end of their service life. Given the population of HSU400 transmissions, the distribution of the ages of that population, and lack of component service histories, some components may fail due to fatigue. Although the IRAM components may be approaching a 600-hour service life during testing at AVTB, it is questionable to extrapolate that service life to the complete transmission in the USMC fleet. However, it is evident that any IRAM solution, which resolves low oil pressures, such as improved seal rings, clutch covers, and improved tube swaging, will greatly extend the service life of the HSU400 transmission.

2.2.2 RAM Transmission Evaluations

Earlier prototype RAM transmission tests revealed a clutch shaft fatigue failure on a component that had a long service life, and a torque converter turbine shaft failure. The RAM tests in progress at AVTB include engine and transmission instrumentation and data acquisition, upgrades resulting from the prototype testing, and the upgraded power engine. The two RAM transmissions include selected and blueprinted components. The selected speed change housings were evaluated on a coordinate measuring machine for dimensional accuracy. Specific attention to the speed change housings included the dowel pin alignment and the line bore perpendicularity to the case and clutch cover mounting flanges. Three speed change housings were screened for RAM use, with one being rejected for being out of tolerance. Cast iron clutch covers and Twin Disc cast iron hook seal rings are also installed. Other changes include two crown gears, a dual plate torque converter clutch, and an enlarged diameter torque converter turbine shaft with a reduced inside diameter bore. As of 4 December 1997, the transmissions have logged 107 and 29 hours.

In order for the RAM testing to be applicable to fielded transmissions, the same quality control and quality assurance procedures utilized to build the RAM test transmissions would be required on the RAM assembly line. The precision inspection procedures may result in a shortage of serviceable components, but ultimately would result in a more reliable transmission

2.3 Review of Gasket Materials, Problems, and Solutions

The gasket leakage stems from the insufficient gasket area (Figure 1), housing warpage (Figure 2), and poor quality gasket material. The access plate on the rear of the transmission, a common leakage area, has a cutout that leaves a very thin gasket surface, plus a very sparse bolt pattern in the same area. Attempts to torque the plate bolts to increase the pressure on the gasket tend to buckle the plate corner effectively reducing the pressure on the gasket. Additionally, a matched end plate and speed change housing may have had the bolt pattern shifted during original production such that insufficient gasket sealing surface remains. Gasket leakage also occurs due to warpage of the speed change housings. The warpage stems from the welding procedures used to repair the cracks in the housings (Figure 3).

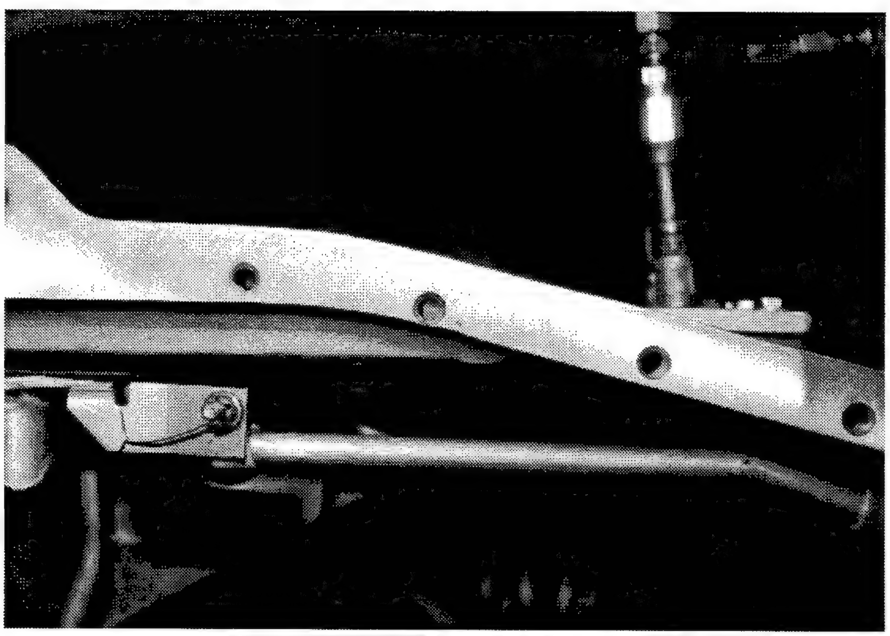

Figure 1. Insufficient Gasket Area

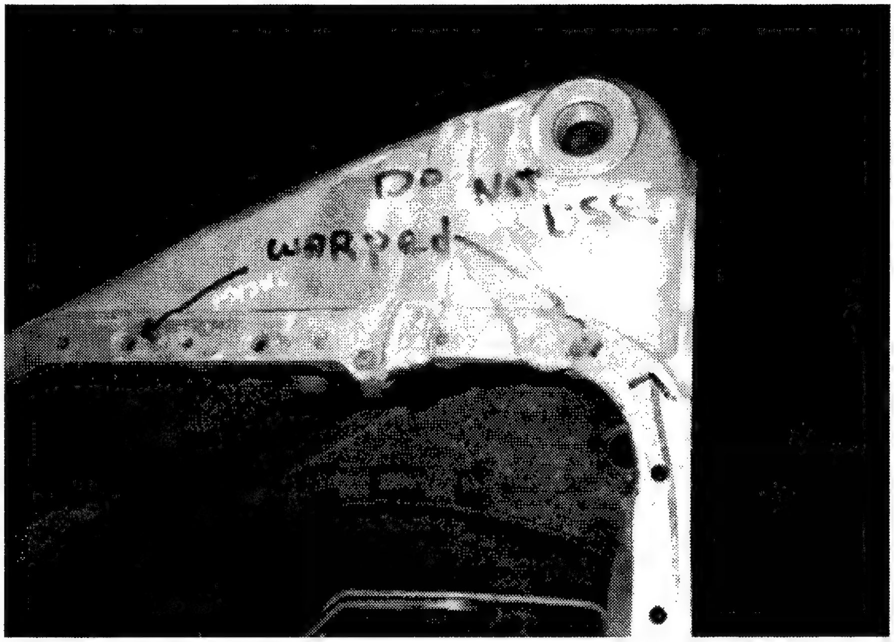

Figure 2. House Warpage

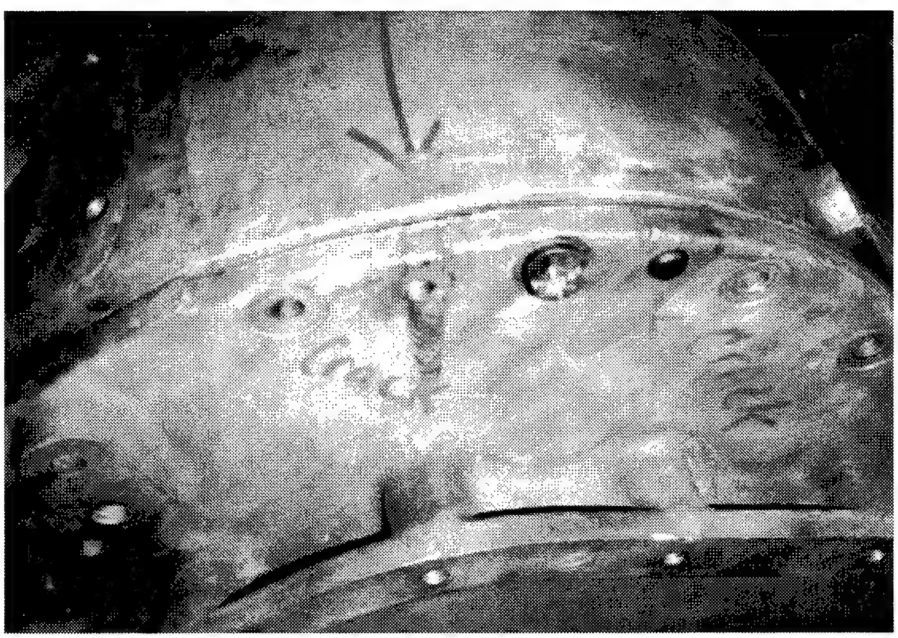

Figure 3. Crack at Dowel Pin Boss

Most of the gasket material problems stem from the requirement for the replacement of asbestos gasket materials. The original speed change housing gasket material was qualified for steam service. When replacement materials were sought by DLA, steam service materials were specified without regard to the actual application. AERA, Inc. investigated the gasket material quality situation, and supplied gasket vendors with the appropriate drawings and application information asking for the vendor's material recommendations. The new gasket materials have been specified and appear to be functioning properly.

AERA currently has an on-going evaluation of gasket materials. The gaskets will be installed and results will consist of a mechanics evaluation of the quality of materials and ease-of-installation. The final result will be observations of any oil drips immediately after filling the transmission with oil, during dyno testing and through final testing and inspection of the vehicle. Results of DEMVAL will be utilized as justification for any required ECPs.

2.4 Product Quality Deficiency Reports (PQDRs) From the Marine Corps Air Ground Combat Center (MCAGCC), 29 Palms, CA

SwRI was tasked to determine if any PQDRs had been issued concerning the IRAM transmission testing at MCAGCC. If any PQDRs had been issued, determine the number of failures and the various failure modes. The PQDRs and Report Control forms are shown in Appendix A. A summary of the failures, for which transmission, the number of hours of operation before failure, and findings are provided in Table 1.

A summary of the PQDRs reveals that 33 of 45 failures (73%) were low oil pressure related; three out of 45 failures (7%) were HSU problems; one out of 45 failures (2%) involved the PTO; and the other eight failures (18%) involved a variety of problems, many still under investigation.

Table 1. FMF Failures - IRAM

Component Affected	ID #	Date	Hours	Symptoms	Findings
Transmission	B5221C	25 November 97	258	Low oil pressure on new "steel rings" after 52 hours of operating	
Transmission	B5222B	Unknown	71	Low oil pressure in forward and reverse gears; 97 psi	
Transmission	B5222B	19 May 97	80	Vehicle will not move until we generate high rpms, then it lunges into gear	Seals replaced, oil pressure normal. Problem not determined
Transmission	B5223B	24 June 97	103	Oil pressure slowly dropped. 1st and 2nd are at 125 psi and 3rd and 4th are 100 psi	Oil seals replaced but vehicle still has low pressure in forward gear; 100 psi
Transmission	B5228B	22 May 97	126	Low oil pressure; 150 psi	
Transmission	B5249B	24 April 97	28	Low oil pressure in forward and reverse gears; forward is 175 psi and reverse is 90 psi	
Transmission	B5328C	25 November 97	166	58 hours of operation on new seals. Transmission pressure is 150 psi in all gears. Vehicle would not move in any gear. Vehicle towed in from the field	
HSU	B5341B	25 August 97	187	Vehicle lost steering	Metal shavings found on magnetic plug
Transmission	B5344B	19 August 97	103	Engine was being replaced when torque converter housing was cracked	Torque converter floated
Transmission	B5347B	25 April 97	33	Vehicle lost all oil pressure during operation. Transmission has no oil pressure in neutral or in gear	
HSU	B6002B	3 March 97	27	Transmission has a knock. No shavings found on magnetic plug	Ship back to Barstow
Transmission	B6003B		54	Low oil pressure in forward and reverse gears	
Trans., HSU	B6004B	9 September 97	274	Vehicle started losing steering. Brass shavings and shavings on magnetic plug were found	Replace HSU and flush transmission
Transmission	B6012B	24 June 97	137	Slowly lost oil pressure all gears; 1st and 3rd pressure was 100 psi; and 2nd and 4th was 125 psi	
Transmission	B6017B	14 October 97	135	5 hrs. of operation on new seals. Vehicle returned from operation with low oil pressure. When oil is hot, oil pressure is 60 psi; when oil is cold, pressures are normal	
Transmission	B6017B	11 July 97	129	Low oil pressure in 2nd and 4th gears; 110 psi	
Transmission	B6018B	24 June 97	133	Low oil pressure	During seal replacement, a crack was found in speed change cover

Table 1. FMF Failures – IRAM (continued)

Transmission	B6033B	6 May 97	94.7	Lost oil pressure; 80 psi. Vehicle could not be operated in any gear	
Transmission	B6034B	12 August 97	80	Low oil pressure in all forward and reverse gears; 150 psi	
Transmission	B6054B	10 April 97	50	Vehicle drove in with low oil pressure; 125 psi	
Transmission	B6054B	22 May 97	50	Low pressure in all gears; 125 psi	
Transmission	B6054B	12 July 97	50	Oil seals replaced. Pressure normal in all gears; 200 psi. Forward gears work. Vehicle will not move in reverse	
Transmission	B6057B	7 April 97	21	Low oil pressure in all forward gears	
Transmission	B6059	19 May 97	20.7	New seals installed. Pressures are fluctuating	
Transmission	B6060B	24 June 97	64	Oil pressure slowly dropped; forward and reverse gears oil pressure is 130 psi	Oil seals replaced; 210 psi oil pressure in all gears. Vehicle will not move in reverse. It appears to have a bad clutch pack
Transmission	B6067B		80	Low oil pressure in forward and reverse gears. Forward has 100 psi in gear; reverse has 120 psi in gear	
Transmission	B6067B	11 July 97	112	Low oil pressure in forward gears; 175 psi	32 hours of operation on new seals
Transmission	B6075B	26 March 97	56	Low oil pressure when put in any gear	
Transmission	B6076B	23 April 97	90	Low oil pressure in forward gear; 90 psi	
Transmission	B6076	10 July 97	117	Original seal test vehicle with B6076B transmission. Neutral oil pressure is 210 psi. Once vehicle is put in gear, oil pressure drops to 140 psi	27 hours on test seals
Transmission	B6076	7 August 97	117	Oil seals replaced. Vehicle will not move in reverse gears. Clutch pack unserviceable	
Transmission	B6068B	11 July 97	186	Low oil pressure in all gears; 120 psi in 2nd and 4th gears; 195 in 1st and 3rd gears	Seals replaced. Transmission is operating normally 28 July 97
Transmission	A6069B	21 July 97	165	Oil pressure dropped to 60 psi	Seals replaced and operations are normal 28 July 97
Trans., HSU	B6078B	14 May 97	23.9	HSU leaking badly from top cover. Lost all power in transmission, no steering, no brakes, and no oil left in the transmission	Seals replaced and oil pressures are normal. Transmission operation is normal 28 July 97
Transmission	B6082B	10 February 97	45	Low oil pressure in forward gears	
Transmission	B6082B	23 April 97	78	Low oil pressure; 97 psi	Transmission also failed at 45 hours. 33 hours since last failure
Transmission	B6106B	28 April 97	33	Low oil pressure in forward gear; 125 psi	
Transmission	B6108B	24 January 97	133	Low oil pressure in forward gears; 140 psi	

Table 1. FMF Failures – IRAM (continued)

Transmission	B6109B	24 June 97	23	Oil pressure slowly dropped to 100 psi in forward gears	Seals were replaced. Good pressure in all gears. Vehicle will not move in reverse gears
PTO	B6122B	18 March 97	66	Pack was pulled for exhaust leak. Found HSU leak at seal. Bearings in PTO output shaft were bad or not shimmed properly	PTO replaced
Transmission	B6131B	3 February 97	34	Torque converter seal leaking	During replacement of oil seal, a broken bearing was found. Transmission floated to Barstow
Transmission	B6131B	7 May 97	70	Oil pressure dropped to 60 psi during operation	
Transmission	3M7522B	11 July 97	69	Low oil pressure in all gears; 150 psi	Seals replaced. Transmission operation is normal 28 July 97
Transmission	389B	20 July 97	130	During test run, 4th gear would not engage, and 3rd gear was slipping. Vehicle has not been operated due to other problems	

Summary

Total Number	45
Low Oil Pressure Related	33
HSU	3
PTO	1
Miscellaneous	8

3.0 AAV PROBLEM OVERVIEW

This phase of the program was designed to evaluate proposed and implemented engineering changes and to determine if other changes would be beneficial. Based on the previous research and studies, the top ten failure modes are:

- Low oil pressure due to seals ring leakage/failure,
- Low oil pressure due to loose swage tubing or broken tubing,
- Worn Wobbler plate and/or slippers in the HSU
- Warpage of housing due to welding
- Fan breaking and damaging housing
- PTO
- Leakage due to inferior gaskets
- Leakage due to poor housing manufacturing
- Improper shimming to provide the proper backlash,
- Lack of parts; 100% replacement items being replaced with reusable old parts.

Most of these problems have been addressed and corrected or are currently under evaluation. The following comments and recommendations are provided.

3.1 Use of New Fluids and Lubricants

Lubricants meeting MIL-PRF-2104 or MIL-L-21260 specifications are qualified for use in transmission. Therefore, the currently specified MIL-PRF-2104 grade 15W-40 oil should meet the AAV operational requirements. Note: Commercially available oils are not required to meet the same testing requirements as MIL SPEC oils. Therefore, they are not interchangeable.

3.2 Filtration System

The IRAM transmission has incorporated a new Parker filtration system, which improved the efficiency and load capacity of the older filtration system (Figure 4). The drawing for this system is shown in Figure 5. This filtration system efficiency is rated as being 50% efficient at 2 μm; 95 % efficient at 8 μm; and 98.7% efficient at 10 μm. The apparent capacity for the Parker system is 200 grams. Based on past experience on other equipment with similar clearance (2), the critical particle size, which can cause significant damage, is approximately 6 μm. Although the

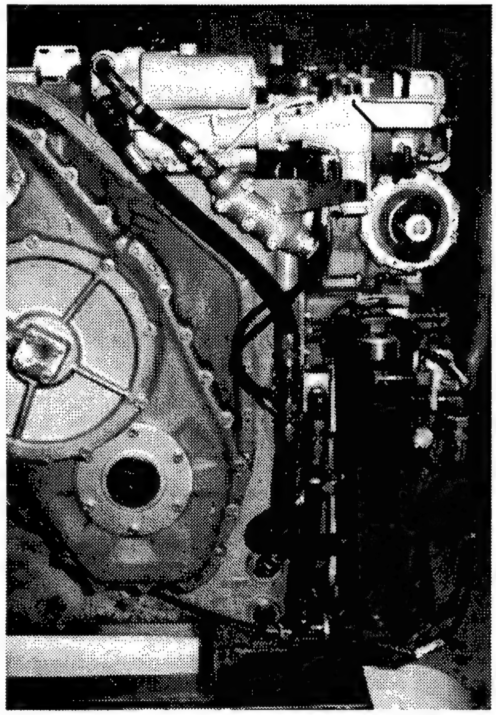

Figure 4. Improved Filtration System

Parker system has improved the filtration performance, for the ultimate practical protection, a 5 μm filtration system should be investigated.

3.2.1 Hydrostatic Steering Unit (HSU)

The HSU has various components with very close tolerances. The incurrence of particulate debris will cause wear and in some cases, catastrophic damage. HSU failures due to slipper problems or overloading due to the unit being undersized continue to be an issue. There are two possible solutions to these problems.

MC3 submitted a suggestion for improving the quality of the oil entering the HSU by modifying the filtration system. The re-plumbing of the oil system would tap into the oil line after the main oil filter (Figure 5). This method would improve the quality of the oil entering the torque converter pump, bypassing other debris-generating components. If approved, modification needs to be evaluated to determine if the oil flow pattern change and pressures effect the operational performance, i.e., AVTB.

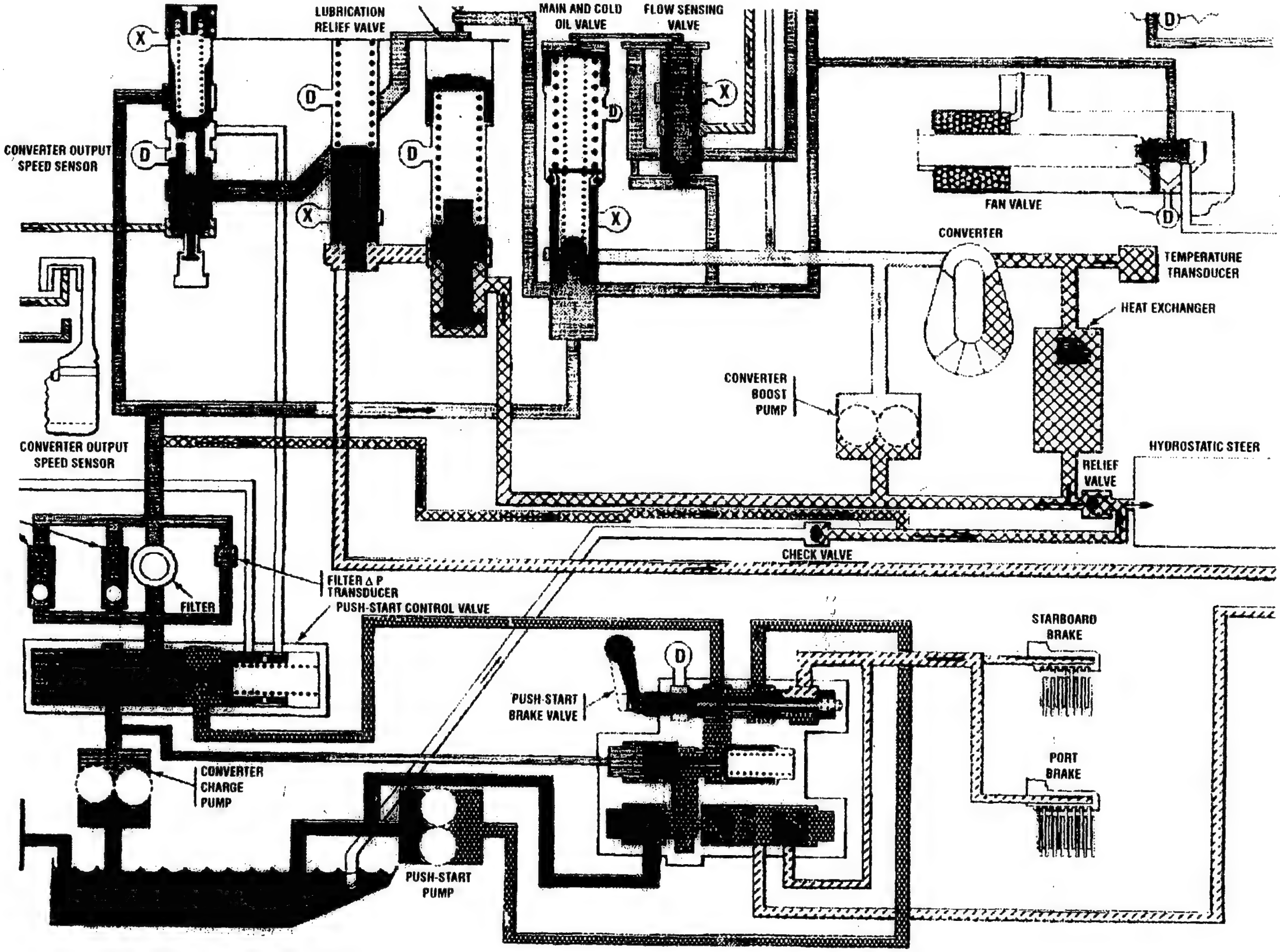

Figure 5. Barstow Recommended Oil Flow Modification

The second possible solution is providing the HSU with its own fluid reservoir as recommended by the OEM.

3.3 Cast Iron Seal Rings

Barstow experienced problems with bronze impregnated Teflon seal rings. As of April 1997, they began experimenting with the Aceomatic cast iron hook seal ring without permission from Albany. As a result of the cast iron ring's improved performance, this ring is being evaluated in a field trial, in conjunction with the Twin Disc cast iron seal ring.

Barstow is installing aluminum clutch shaft covers with cast iron sleeve inserts on the IRAM transmissions. There is some question on the roughness of the surface finish of the cast iron sleeve being produced by Barstow. The specified finish is R_a 50-63 μin. However, the delivered covers are in the 85-90 μin range. The roughness standards and measurement procedures need to be evaluated.

An inspection team visited the MCAGCC, EEAP Battalion, Ordnance Maintenance Office at 29 Palms, CA to inspect six IRAM transmissions that had cast iron sleeved clutch covers and cast iron hook seal rings installed. The agenda was to determine if the cast iron seal ring/sleeve combination would result in improved reliability. A secondary agenda was to determine if either of the seal rings from two differing manufacturers had superior performance. The transmission inspections are summarized in Table 2. The seals on each clutch shaft were numbered with 1 being the inboard seal, 2 the center, and 3 the outboard seal looking at the shaft. All non-broken cast iron seal rings were re-installed to continue the evaluation. It was apparent the Aceomatic seal ring was not polishing the cover (Figure 6), remaining stationary in the cover, and the seal rings displayed slightly more side polish. The Twin Disc seal rings demonstrated polishing that was not unrealistic for the number of hours on the transmission (Figure 7). It was concluded that the Aceomatic seal ring was the preferential solution because the seal ring was wearing instead of the cover.

Table 2. IRAM Transmission Inspections at MCAGCC

Serial no.	B6003B	B5320B	B6059A	B6075B	B3M7733B	B5249B
Hours	127	84	146	146	154	98
F/R Cover R_a	66	77	66	76	65	69
F/R Cover Condition	Polished	Polished	No polish	Polished	No polish	No polish
F/R Seal Ring Condition	1 both sides polish	1 minor polish	1 minor polish	1 minor polish	1 minor polish	1 excessive inboard polish
	2 both sides polish	2 minor polish	2 minor polish	2 minor polish	2 minor polish	2 minor polish
	3 broke on removal	3 minor polish	3 minor polish	3 minor polish	3 minor polish	3 minor polish
1/3 Cover R_a	70	66	68	65	73	65
1/3 Cover Condition	Polished; slight groove	Polished	No polish	Polished	No polish	No polish
1/3 Seal Ring Condition	1 minor polish	1 minor polish	1 minor polish, heavy shaft chamfer	1 minor polish	1 minor polish	1 minor polish
	2 minor polish	2 minor polish	2 minor polish, heavy shaft chamfer	2 minor polish	2 minor polish	2 minor polish
	3 minor polish	3 minor polish, broke on removal	3 minor polish, heavy shaft chamfer	3 minor polish	3 minor polish	3 minor polish
2/4 Cover R_a	70	66	64	63	70	78
2/4 Cover Condition	Polished	Polished	No polish	Polished; 3 grooved	No polish	No polish
2/4 Seal Ring Condition	1 minor polish	1 minor polish	1 minor polish	1 minor polish	1 minor polish	1 minor polish
	2 minor polish, ring spun, shaft burr	2 minor polish	2 minor polish	2 minor polish	2 minor polish	2 minor polish
	3 minor polish	3 minor polish	3 minor polish	3 minor polish, tight side clearance	3 minor polish	3 minor polish
Ring Supplier	A	A	B	A	B	B

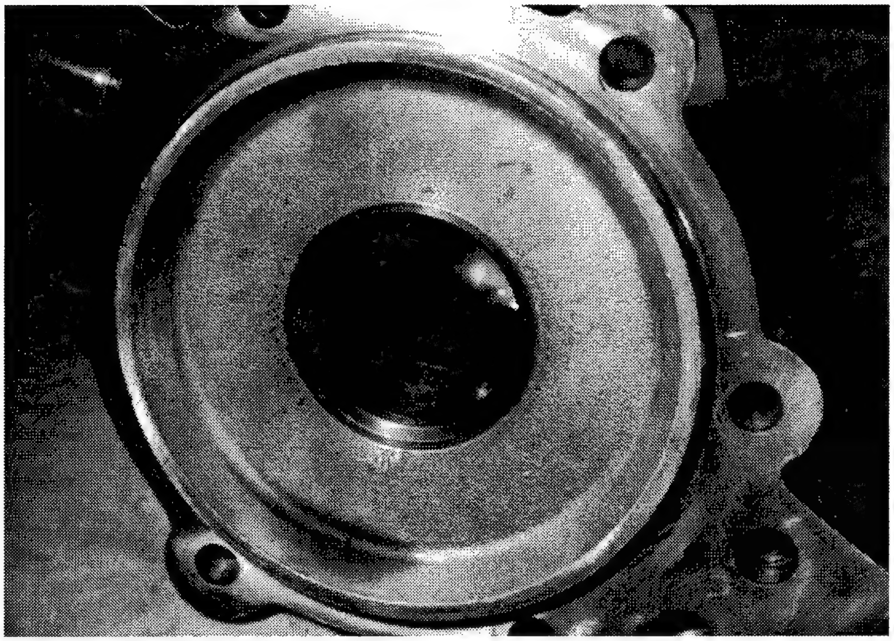

Figure 6. <u>**Inside Cover Using Aceomatic Seal Rings**</u>

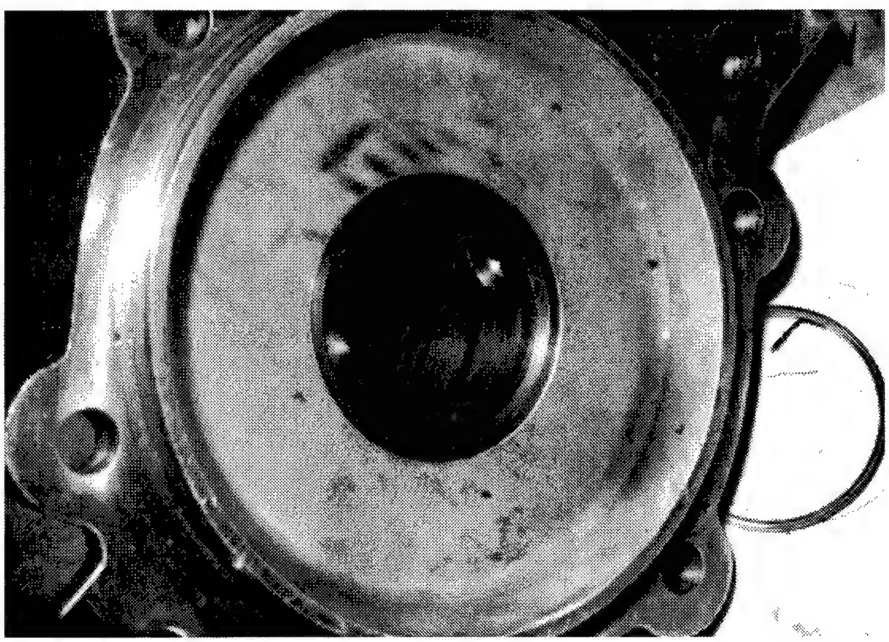

Figure 7. <u>**Inside Cover Using Twin Disc Seal Rings**</u>

3.4 Wobbler Plate in Hydrostatic Steering Unit (HSU)

The hydrostatic steering unit (HSU) consists of a fixed-displacement swash-plate rotary motor and a variable-displacement swash-plate pump. The vehicle operator steering input varies the direction and magnitude of the angular displacement of the swash-plate of the variable-displacement pump. Piston seizures of the variable-displacement pump had occurred. The pump inspected revealed scratches in the piston bores, which indicated contamination. The present filtration system allows unfiltered bypass oil to reach the HSU during specific startups. The HSU contains an intake port filter, but does not utilize an exhaust port filter. Inferior piston slippers from an aftermarket supplier caused the HSU problems. The slippers wore causing contact between the piston and wobbler plate, causing the HSU failure. These problems have been solved. MC3 engineered a procedure to recover damaged HSU wobbler plate and the piston slippers are now being supplied by the original equipment manufacturer.

3.5 Speed Change Housings

Speed change housing problems included housing cracks from jackscrews (Figure 8), fan drive universal joint failures, tubing swages, mismatched nylon tube locating blocks, bearing bore damage from spun bearings, and housing warpage from crack welding procedures.

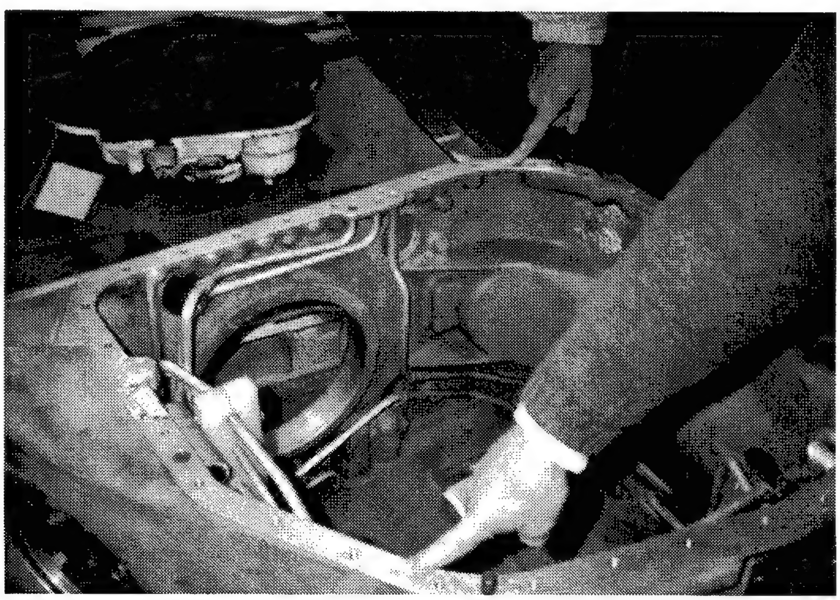

Figure 8. Flange Deformation Due to Jackscrews

3.5.1 Speed Change Housing Cracks

Housing cracks appear due to disassembly and handling procedures and incorrect vehicle operation (Figure 3). Each time a transmission is rebuilt increases the likelihood of speed change housing damage. An example is that a crack typically shows up at a location consistent with the lower jackscrew used to separate the end plate from the speed change housing. It was noticed that there was localized yielding of the aluminum housing material at all jackscrew locations. Cracks were evident at the lower speed change housing dowel pin boss (Figure 3). The cracks in the dowel pin boss are typically repaired with Devcon epoxy putty. Another typical speed change housing crack occurs due to failure of the fan drive universal joint. The fan drive universal joint fails, and the flailing drive shaft impacts the speed change housing causing cracks. An ECP was developed to prevent this damage but was never implemented.

3.5.2 Bearing Bore Damage

Inspection of several speed change housings indicated the bearings for the clutch shafts have been spinning within the bearing bores. The bearing press-fit is obtained by heating the aluminum housings to 300°F and cooling the steel bearing to -38°F. AERA, Inc. analysis suggests when the housing and bearings reach room temperature; the stress in the housing bores exceeds the yield strength of the material, relieving some of the press-fit (Figure 9). When the transmission reaches its operating temperature in the 190-210°F range, the greater thermal expansion of the housing relieves the press-fit and allows the bearings to spin. Housing bearing bores, which reveal extensive damage from spun bearings, are sleeved with a material of higher yield strength.

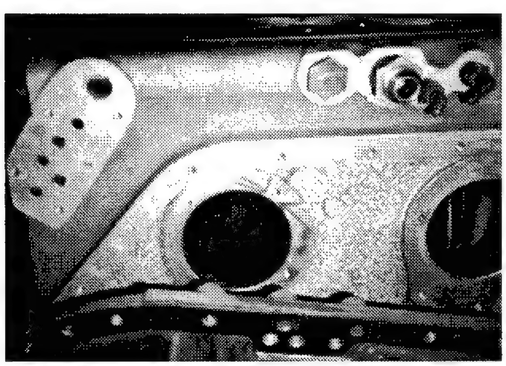

Figure 9. <u>Bearing Bore Damage</u>

3.6 PTO

The problems with the PTO's include distortion of the fan drive idler shaft holes and the unavailability of the HSU drive shims. The fan drive idler shaft holes are distorted due to localized yielding of the aluminum PTO case material. Both logistic bases drill out the idler shaft holes and then sleeve the holes with a steel insert. The HSU drive shims are used to set the backlash of the bevel gear. The procedure calls for 100% shim replacement, but old shims still in good condition are being reused due to the unavailability of new shims.

4.0 TEST REQUIREMENTS

4.1 Seal Rings

Evaluation of the two candidates seal rings, Aceomatic and Twin Disc, reveals differences in the physical characteristics of the materials and manufacturing quality. This initial investigation was limited to only a handful of samples. It is recommended that additional samples be evaluated to confirm these initial results.

4.1.1 Seal Ring Composition

Cast iron is widely used for components that must resist wear. Different types of cast iron, however, exhibit wide differences in wear characteristics. Complicating matters, these differences often do not correlate with commonly measured properties of the cast iron. The two types of cast iron seal rings included in the transmission test exhibited such differences in behavior. For example, the cast iron sleeves mated with the Aceomatic seal rings showed no visual evidence of wear, while the seals themselves showed minimal amounts of wear. In contrast, the sleeves mated with the Twin Disc seal rings showed polishing of the sleeve surface and minor wear while the ring seals showed only minimal visual evidence of wear. The wear appeared to occur preferentially on the seal ring when the Aceomatic seal rings were employed and in the sleeve when the Twin Disc seal rings were employed. Localizing the wear on the seal ring is considered to be the preferred condition.

In order to gain a better understanding of the differences in the wear behavior exhibited by these two seal rings, new and used seal rings from both suppliers underwent further evaluation at SwRI. Hardness tests were performed on the four seal rings. A 30T scale was used due to the limited size of the rings. The 30T hardness values were converted to Brinell values for comparison with the specified hardness (190 to 240 Brinell) of the cast iron sleeve. The hardness values are listed below:

Aceomatic (new):	184 Brinell
Aceomatic (used):	184 Brinell
Twin Disc (new):	179 Brinell
Twin Disc (used):	173 Brinell

It is evident from these results that both seal ring materials are softer than the specified hardness of the cast iron sleeve. Thus, the hardness values do not explain the differences in the wear behavior of the two seal rings.

Following the hardness tests, the seal rings were examined under a low power stereomicroscope and in a Scanning Electron Microscope (SEM). The new Twin Disc seal ring exhibited chipping along the machined edges (Figure 10). A large radial crack was also present in the new ring (Figure 11). The broken Twin Disc seal rings (Figure 12), removed from the transmissions at MCAGCC exhibited more extensive chipping than the new seal ring.

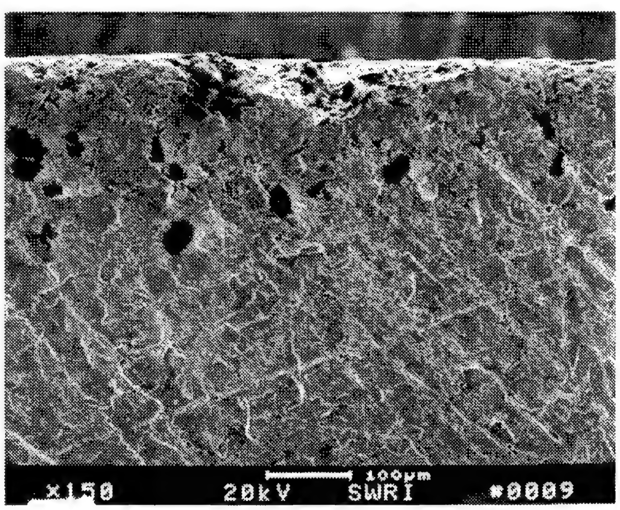

Figure 10. New Twin Disc Seal Ring

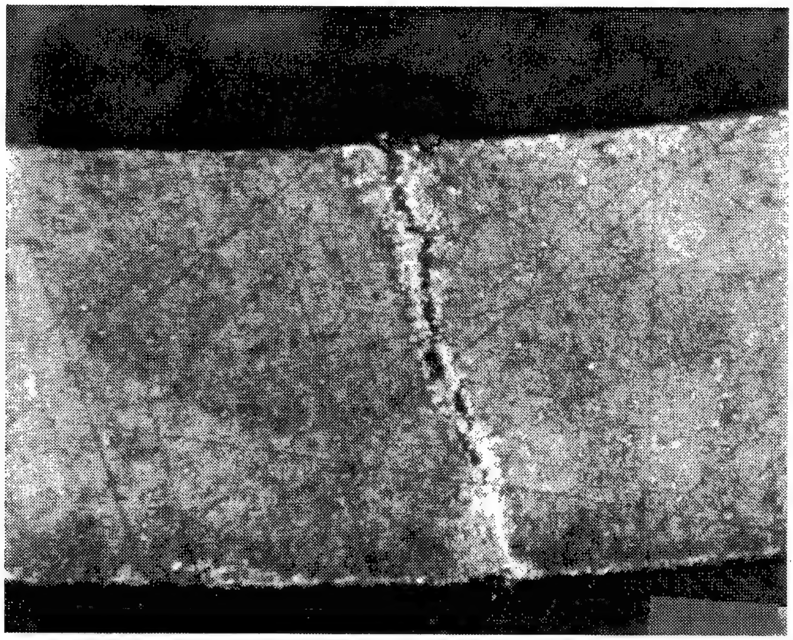

Figure 11. Cracked New Twin Disc Seal Ring

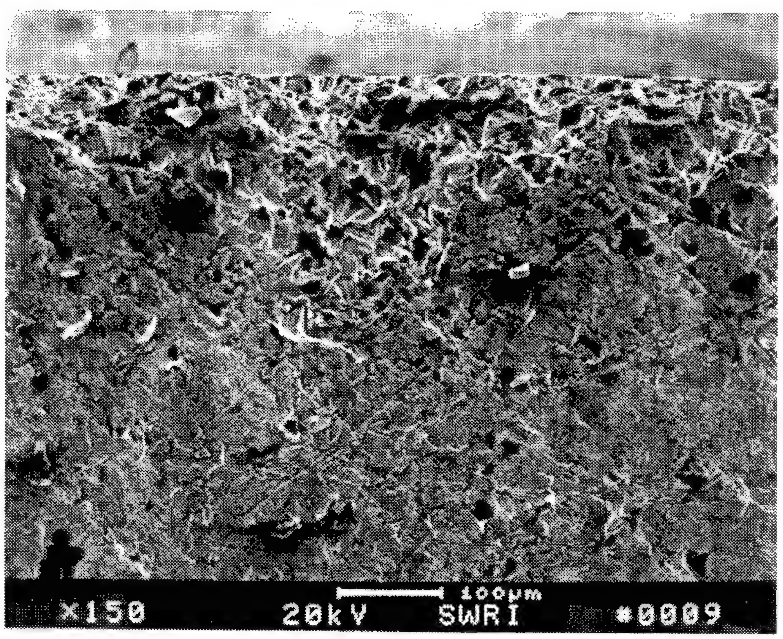

Figure 12. Used Twin Disc Seal Ring

The appearance of the new Aceomatic seal ring was very different from that of the new Twin Disc seal ring. Very smooth edges, as shown in Figure 13, were evident around the entire ring, and no evidence of chipping or cracking was observed. The used Aceomatic seal rings that were delivered to SwRI from Barstow also exhibited smooth edges that were free of chipping and cracking, Figure 14.

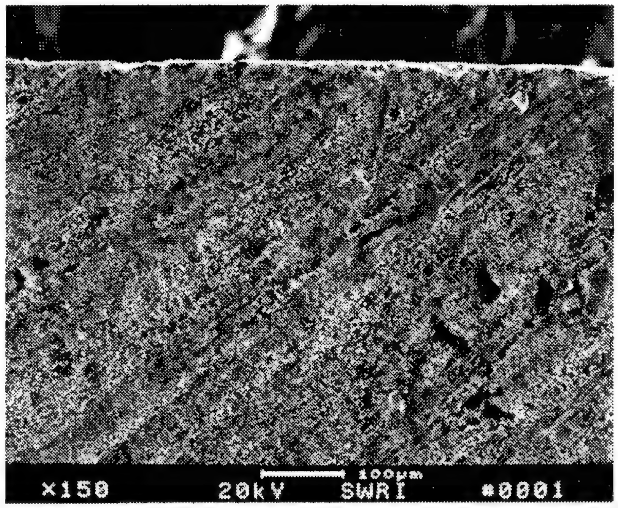

Figure 13. **New Aceomatic Seal Ring**

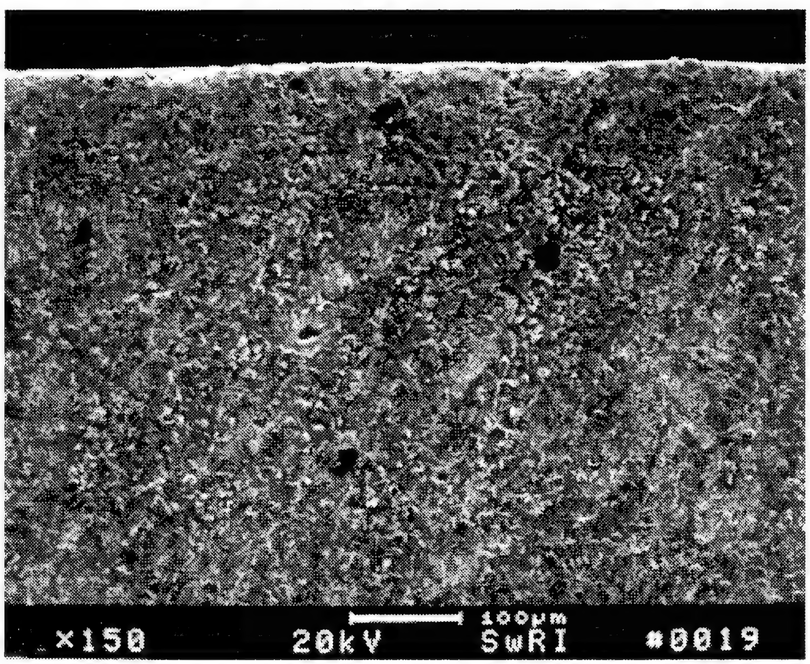

Figure 14. **Used Aceomatic Seal Ring**

New and used, bronze impregnated, Teflon seal rings were also examined. As expected, their appearance was very different from either of the cast iron seal rings (Figures 15 and 16). However, due to the very different nature of the material of the rings, it is impossible to draw any conclusions about Teflon relative to cast iron seal rings from these micrographs.

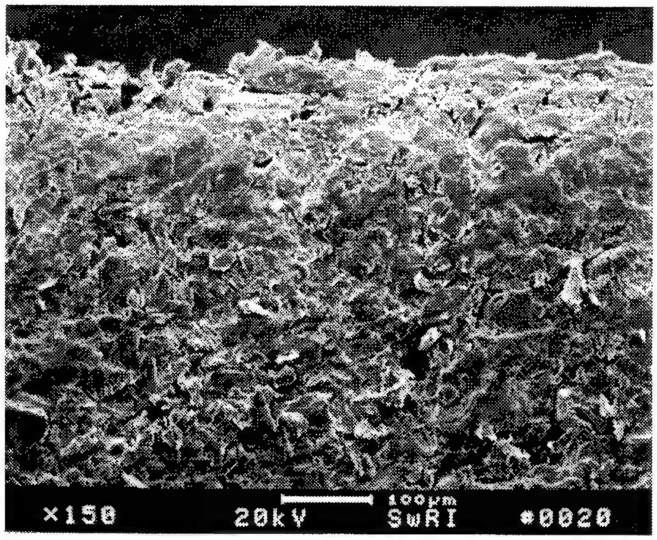

Figure 15. New Teflon Seal Ring

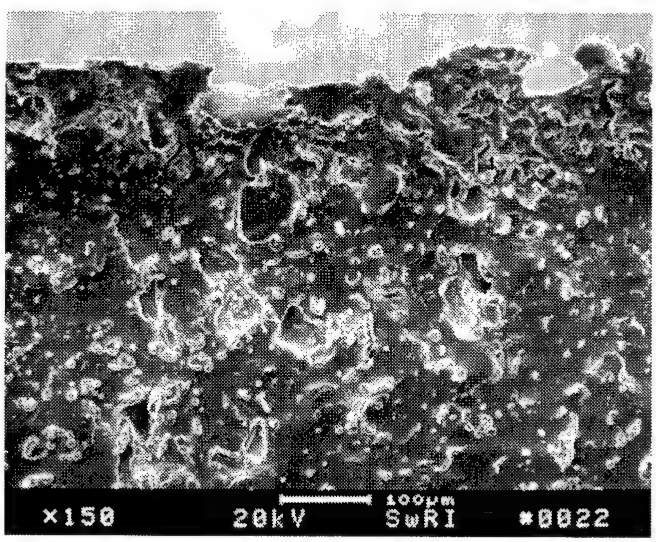

Figure 16. Used Teflon Seal Ring

In summary, although the Twin Disc seal rings performed reasonably well during the transmission test at MCAGCC, subsequent examination of the seal rings indicated that an undesirable wear mechanism (edge chipping) was operating during the test. This wear process produces sizeable wear particles that can cause 3-body abrasive wear of the mating surfaces. The wear that was observed on the cast iron sleeves was likely a result of such wear. Wear of this type can also lead to accelerated wear rates and catastrophic failures. Additionally, the condition of the new Twin Disc seal ring that was examined was unacceptable due to the presence of the large radial crack and a significant amount of edge chipping. Although a single sample may not be representative, the appearance of similar radial flaws on the two used Twin Disc seal rings suggests that these types of flaws may be widespread. In our opinion, the poor manufacturing quality and the presence of an undesirable wear mechanism make the Twin Disc seal rings unacceptable for the proposed application. These seal rings should not be considered as a secondary source.

4.2 Welding Procedures

Welding repairs are performed on the castings to repair damaged threads and cracking. Both Albany and Barstow indicated that the castings are preheated to 300°F to 350°F prior to welding. Tungsten inert gas (TIG) welding is employed. Although general welding guidelines were available, specific written welding procedures were not.

The major problem encountered during weld repairs at both Albany and Barstow was excessive warpage of the castings. Barstow employs prestressing rods to deflect the housing surface 0.020" past center. The case is then heated to between 450°F and 500°F, at which point the rods are "snugged up." The case temperature is lowered to 350°F for the actual welding repair.

The primary concern related to the weld repairs is the lack of a well documented welding procedure. Discussions with personnel from both depots revealed some welders had a high success rate while others were very poor. Without such a procedure, significant variation exists internally besides between the two rebuild facilities. Implementation of a well-documented, written weld repair procedure common to both Albany and Barstow would improve the quality and consistency of the

weld repairs. Once the documentation is implemented, a training program for all welders would further improve the weld quality.

A secondary concern is the effect of the weld repair on the strength of the castings. Most castings have been in service for over thirty years, and many may have seen multiple weld repairs over this time frame. The first issue that needs to be examined is the strength of the actual weld repair. The strength of the repair region relative to the strength of the casting needs to be documented. The second issue that needs to be examined is the effect of the thermal exposures employed during the welding on the properties of the castings. The castings are supposedly alloy 356-T6. In the T6 condition, 300°F to 350°F preheating should not produce significant over aging unless the exposure times become excessive. Heating to 450°F to 500°F, as reportedly performed by Barstow, is more likely to cause measurable over aging. However, for most reasonable exposure times, these higher temperatures would also not be expected to significantly degrade the casting properties.

The uncertainties related to the strength of the weld repairs and the residual strength of the castings could be alleviated by a limited test program. Castings that are considered unserviceable, for example, due to excessive warpage, could be utilized for such testing. Documentation of these strength issues becomes more important as the weight and horsepower of the AAV are increased.

4.3 Tube Swage

With the high probability that the oil seal ring problem has been resolved by use of the cast iron hook ring, the tube swaging problem may become the next major cause of returned transmissions. AERA, Inc. was tasked, AIN 65-T019, to review the swaging process of the oil tubes into the transmission cases.

The problem is once the tubes are swaged into their respective holes (Figure 17); vibration of the material loosens the fit. In addition, if the tube swaging process is not performed correctly, the tubing wall thickness becomes very thin, cracking as a result of fatigue. Both of these problems result in the loss of oil pressure.

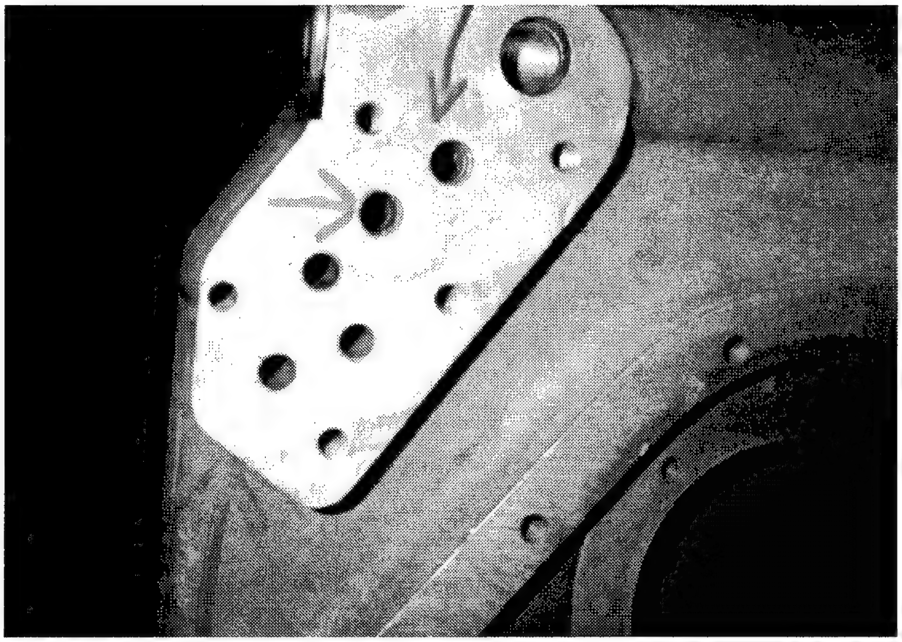

Figure 17. Tube Swage Problem Areas

The proposed method for the tube swaging is to set a limit on the hole diameters, then swage the tube until the ID of the tube is within a prescribed limit. The procedure will result in a 5% to 15% swage of the tube. The advantages of this method are that the number of measurements is reduced and no calculations are required. It will also be easy to determine in a post inspection if the tubes were properly swaged simply by measuring the ID of the installed tubes. The ability to check the degree of swage of an installed tube will be very helpful toward eliminating the improperly installed swage tubes. Although this procedure should aid in reducing the number of tubing swage problems, it is felt that this problem needs additional investigation to produce a better solution.

5.0 OTHER OBSERVATIONS

5.1 Used Oil Analysis

An oil sample (AL-25192-L) from transmission SN:534 at Albany was obtained for viscosity and wear metals analysis. The transmission plate indicated it was last overhauled May 1992 and was removed from a vehicle showing 852 hours and 3397 miles. Personnel indicated that often the worst case components at a unit are put in one vehicle that is shipped to the depot. There was no tracking

of the actual utilization history of the transmission. An additional sample (AL-25244-L) was obtained from MC3 from a vehicle, which was in for re-build. No data was provided for this sample. The analysis results for these oil samples are shown in Table 3.

Table 3. Transmission Lubricant Analysis

Sample	AL-25192-L	AL-25244-L
Location	Albany, GA	Barstow, CA
Kinematic Viscosity @ 100°C, ASTM D445, cSt	9.26	13.89
Wear Metal by ICP, ASTM D5185, ppm		
Mn	1	1
Mg	340	369
Fe	46	40
Cr	<1	<1
Cu	354	102
B	120	137
Ba	3	<1
Ag	1	<1
Al	10	3
Zn	915	850
Sn	1	2
Si	8	8
Sb	<1	<1
P	863	774
Pb	181	23
Ni	<1	<1
Mo	62	74
Ca	1652	1805
Na	13	3

The viscosity measurement of sample AL-25192-L indicated it was a SAE 30-weight lubricant. An SAE 30 lubricant has a 9.3-12.5 cSt kinematic viscosity range at 100°C. The wear metal analysis indicates a zinc (Zn) and phosphorus (P) anti-wear additive plus a calcium (Ca) and magnesium (Mg) dispersant/detergent system. The copper (Cu) and lead (Pb) wear metals appear high, which probably indicates the presence of bronze. This could indicate clutch wear or HSU slipper shoe wear. This type of wear would be expected in a non-IRAM transmission due to the type of clutch plates previously used.

The viscosity measurement for AL-25244-L indicates SAE 15W-40 grade lubricant. A multi-viscosity SAE 15W-40 lubricant has a 12.5-16.3 cSt kinematic viscosity range at 100°C. Wear metal analysis indicates a zinc (Zn) and phosphorus (P) anti-wear additive plus a calcium (Ca) and magnesium (Mg) dispersant/detergent system. The copper (Cu) and lead (Pb) wear metals are evident but these levels would probably be considered normal.

5.2 Speed Change Housing Cover Cast Iron Sleeve Roughness Measurements

Since the speed change cover cast iron sleeve roughness is an important finish, it was questioned why each depot uses a different model profilometer and measure different values. In order to possibly answer these questions, three speed change covers from each depot were supplied to SwRI to measure the surface roughness and confirm each depot's results.

All six speed change housing covers were measured using two different profilometers and different cut-offs. One set of surface roughness measurements was performed using a Surtronic 3P profilometer manufactured by Taylor-Hobson. The pick-up for this instrument is a variable reluctance type transducer, which is supported on the surface to be measured, by a skid, as shown in Figure 18. The radius of curvature of the skid is much greater than the roughness spacing, so it rides across the surface almost unaffected by the surface roughness. Prior to performing the measurements, the instrument was calibrated in 118 μin and 14 μin calibration blocks. The R_a value of the surface roughness of the speed change housing covers was measured using a 0.52 inch stroke length and a 0.1 inch cut-off. Measurements were made at three locations for each cover.

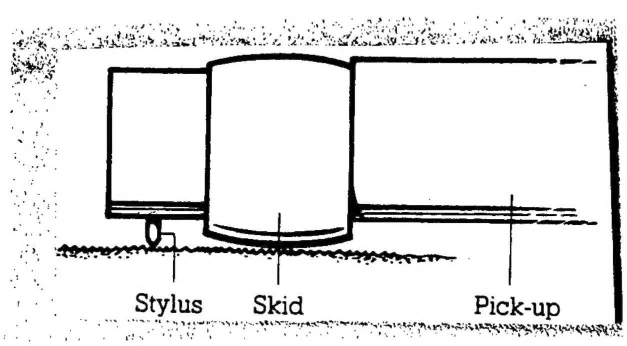

Figure 18. Surtronic 3P Profilometer

The second set of measurements was performed using a Talysurf 6 profilometer manufactured by Taylor-Hobson. The Talysurf 6 has a variable inductance transducer, which can be used either with or without a skid, although a skid was used for these measurements. Prior to performing the measurements, the instrument was calibrated using a 32.5 μin calibration block. The R_a value of the surface roughness was measured using a 1" stroke and a 0.03" cut-off. These are similar test conditions to Barstow. Measurement conditions were not supplied by Albany. Each measurement and their averages for each cover are shown in Table 4.

Table 4. Profilometer Measurements of Speed Change Housing Covers

Sample	Depot Reading	SwRI 1	SwRI 2	SwRI 3	Ave	SwRI* 1	SwRI* 2	SwRI*	Ave*
Albany	**46**	19.6	24.3	25.6	**23.2**	16	24	38	**23**
Albany	**48**	41.2	51.8	53.3	**49.3**	43	46	59	**49**
Albany	**56**	68.7	67.8	65.1	**67.2**	68	77	67	**71**
Barstow	**55**	57.3	58.5	61.7	**59.2**	77	61	69	**69**
Barstow	**50-54**	56.9	51.3	48.6	**52.3**	32	66	53	**50**
Barstow	**55**	41.0	51.2	56.4	**49.5**	122	91	71	**95**

* Surtronic 3P Measurements

The above results illustrate the need to use the similar instruments and to insure each depot is measuring the same value, R_a, with the same cut-off. As shown in **Figure ?**, even though the roughness is similar, using the 0.1 cut-off illustrates the "waviness" in this speed change housing cover. As previously mentioned in the welding section, a documented procedure with the proper training is needed to provide a consistent and repeatable finish.

5.3 Failure and Component Accountability

The importance of tracking failures cannot be overemphasized. First, knowing the failure modes allow the mechanics the fix the problems immediately instead have to troubleshoot the system.

Second, and most important, tracking failures allows the USMC to determine if a component is beginning to reach its useful life and needs to be replacement on a fleet-wide scale, if a production batch was produced out-of-specification, or if replacement parts have changed due to change in vendors. Without a tracking system, any information is only speculation. AERA is currently working on a tracking system, but discussions at Barstow illustrated that the USMC still has not decided how to perform this task or even if it is needed.

5.4 Communication Between Depots

In our discussions with each depot, it was evident that the two depots do not always communicate with each other and often within their own depot. Often, a mechanic was able to tell us where a transmission had last been rebuilt just by looking at certain repair items. They would say, "This was rebuilt at Barstow (or Albany) because they do that and we do not."

Some of the differences between the depots are understandable in that California has different EPA regulations, which restricts Barstow from performing some procedures. However, the biggest difference between the two depots was in their welding procedures. As previously mentioned, this issue needs to addressed, be it quarterly meetings to discuss potential new methodologies, or training sessions, better communication needs to be established.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

In conclusion, most of the issues, which have been identified, have been addressed, using good engineering practices. The major problem in the field, low oil pressure due to seal leakage, appears to have a high probability of success. The tube swage appears to be the next problem area and AERA is currently addressing it. However, paper studies and limited testing often do not give a good or complete picture. So far it appears that most studies have been successful, but as shown with the cast iron hook seals, if quantitative analysis is not performed, some information is lost.

6.2 Recommendations

Overall, the discussed AAV improvements should greatly increase the combat readiness of this vehicle. To provide to USMC with a better forecast of potential problems, SwRI recommends the USMC keep a close watch on the tube swage issue. It could be the next "showstopper." A track system needs to be instituted. The Marines need to decide if they can afford to keep all components on a vehicle and still meet combat readiness levels or if parts are interchangeable, how are you going to track them.

Although the AAAV will be coming on line in the near future, the AAVs will probably still be in the field for another 10-15 years. Evaluation of the housing integrity to determine if it will survive that long should be addressed by the MCs or PM-AAV.

If a secondary source is required for the cast iron hook seal rings, analysis of this material needs to perform. If the USMC can get it from Aceomatic and its manufacturer or it has to be determined. The other solution is to go back to Twin Disc and have them meet these new requirements with their seal ring.

7.0 REFERENCES

1. IRAM Transmission: Historical Research and Failure Data Analysis, Volumes I, II, and III, prepared by AERA, Inc., John Palmer, 21 May 1997.

2. "Filtration Requirements and Evaluation Procedure for a Rotary Injection Fuel Pump," Bessee, Gary B., et al., Society of Automotive Engineers Paper 972872, October 1997.